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(54) Scanning capacitive semiconductor fingerprint detector

(57) A scanning fingerprint detection system that includes an array of capacitive sensing elements. The array has a first dimension greater than the width of a fingerprint and a second dimension less than the length of a fingerprint. Each of the capacitive sensing elements has a size less than the width of a fingerprint ridge. Circuitry is provided for scanning the array to capture an image of a portion of fingerprint and for assembling the captured images into a fingerprint image as a fingerprint is moved over the array.

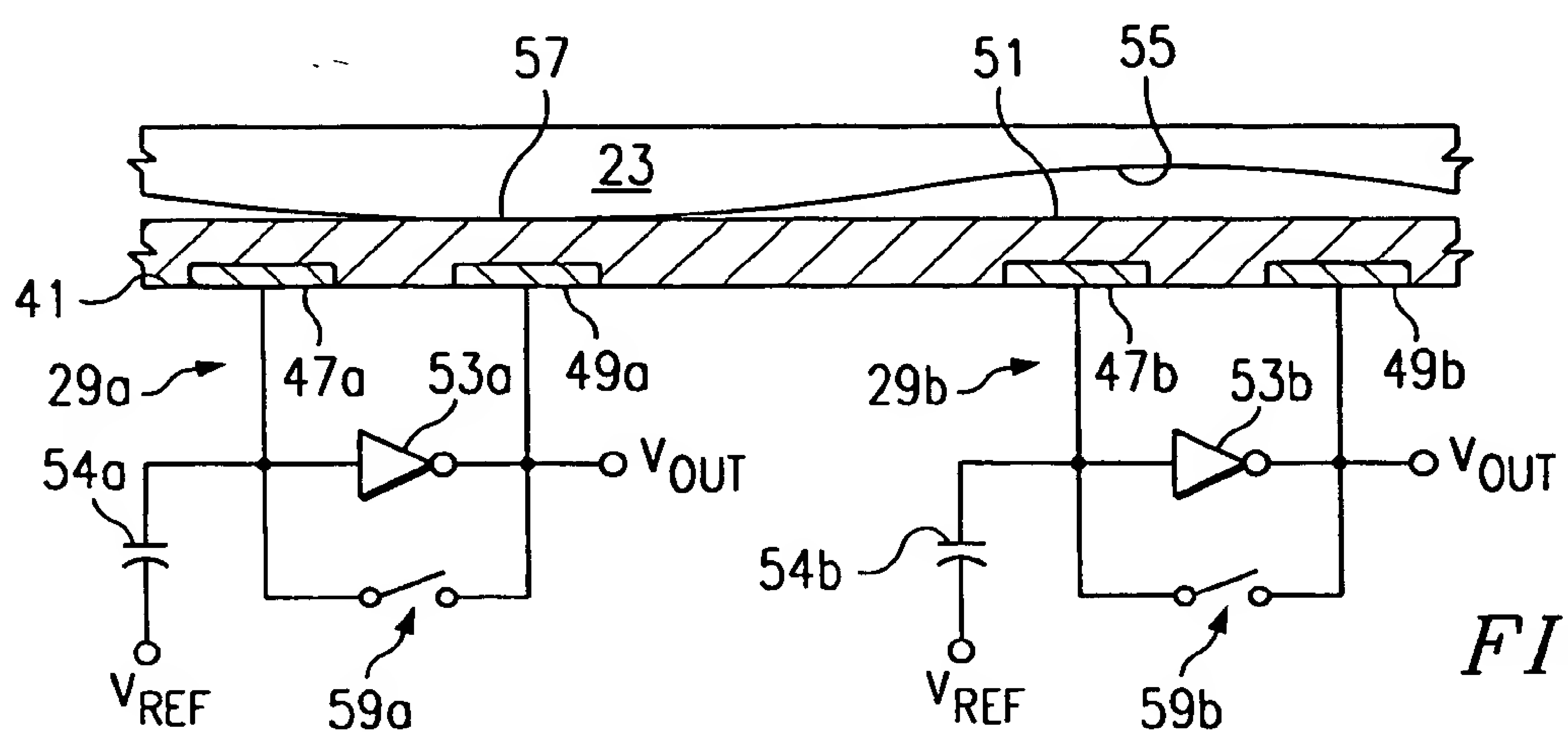

FIG. 3

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Description

[0001] The present invention relates generally to methods of and systems for capturing fingerprint images, and more particularly to a semiconductor capacitive fingerprint scanning device.

[0002] Fingerprint recognition has been suggested for use in many security applications such as controlling access to buildings, computers, or the like. Fingerprint recognition systems enable a user to access the controlled facility without a device such as a key or smart card or without having to memorize a password or other personal identification number.

[0003] The sensing device is an important part of a fingerprint recognition system and the quality of the representation of the fingerprint that the device produces will affect recognition capability and the amount of processing required for verification of the fingerprint. Various technologies have been proposed for use in fingerprint sensing devices. One commonly proposed technology involves optical detection. Examples of optical fingerprint detection devices are disclosed in Jensen, U.S. Patent No. 4,784,484; Fishbine, et al., U. S. Patent No. 5,467,403; and Giles, et al., U.S. Patent No. 5,548,394.

[0004] Optical detectors include a glass surface upon which a subject places his finger to be recognized. Optical detectors may present recognition problems when the glass surface or the subject's finger is wet. The optics of the detectors are constructed based upon the indices of refraction of air and glass. When water or perspiration is between the glass and the surface of the finger, the operation of the detector is affected.

[0005] In addition to optical sensors, various electrical sensor systems have been proposed, as for example in Knapp, U.S. Patent No. 5,325,442; Tamori, U.S. Patent No. 5,400,662; and Tamori, U.S. Patent No. 5,429,006. The electrical detection devices typically comprise an array of sense elements. The individual sense elements respond with an output that depends upon whether a fingerprint ridge or valley is located over the sense element.

[0006] The electrical detection devices offer advantages over the optical detection devices. However, an electrical detector that is large enough to detect a fingerprint is a large and expensive semiconductor device. For example, the TouchChip (TM) Silicon Fingerprint Sensor (STFP2015-50) available from SGS-Thomson Microelectronics has an active sensor surface measuring 19.2mm by 12.8mm that includes a 384 by 256 sensor array. Accordingly, electrical detection device tend to be more expensive than optical detectors.

[0007] It is an object of the present invention to provide a fingerprint detecting device that overcomes the shortcomings of the prior art.

[0008] The present invention provides a scanning fingerprint detection system that includes an array of capacitive sensing elements. The array has a first dimension about the width of a fingerprint and a second dimension substantially less than the length of a fingerprint. Each of the capacitive sensing elements has a size less than the width of a fingerprint ridge. Circuitry is provided for scanning the array to capture an image of a portion of fingerprint and for assembling the captured images into a fingerprint image as a fingerprint is moved over the array.

[0009] Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings in which:

[0010] Figure 1 is a block diagram of a system according to the present invention.

[0011] Figure 2 is a block diagram of a sensor array according to the present invention.

[0012] Figure 3 illustrates the physical structure and electrical operation of individual sensor cells according to the present invention.

[0013] Figure 4 illustrates a sequence of partial fingerprint images captured according to the present invention.

[0014] Figure 5 illustrates a fingerprint image assembled according to the present invention from the partial images of Figure 4.

[0015] Referring now to the drawings, and first to Figure 1, a fingerprint scanner according to the present invention is designated generally by the numeral 11. Fingerprint scanner 11 includes a scanning array 13, which captures an image of a fingerprint, and a suitable output 15. Scanning array 13 is preferably fabricated on a single semiconductor chip.

[0016] Scanning array 13 is rectangular in shape and has a width about the width of the surface of a finger 17 that contacts scanning array 13. In the preferred embodiment, scanning array 13 is about one-half inch or 12.8mm wide. The length of scanning array 13 is substantially less than the length of the end of finger 17, and in the preferred embodiment, the length of scanning array 13 is about one-tenth inch or 2.5mm. As will be described in detail hereinafter, fingerprint scanner 11 captures a fingerprint image as finger 17 is swept over scanning array 13.

[0017] Referring now to Figure 2, there is shown a block diagram of scanning array 13. Scanning array 13 is preferably integrated into a single chip, and it includes a rectangular array 27 of cells 29 of the type illustrated in Figure 3 hereof. Each cell 29 is smaller than the width of a fingerprint ridge.

[0018] In the preferred embodiment, cells 29 are on a pitch of 50μm, which corresponds to a resolution of about 508 dpi. The exact number of rows needed depends upon the capabilities of the image regeneration software as well as the maximum finger speed and the frame rate at which array 27 is scanned. The number of rows must be sufficient so that, when the finger is moving at its maximum speed, a pair of consecutive frames has enough rows in common for them to be aligned by the regeneration algorithm. The more image rows in

common from one frame to the next, the more exactly the regeneration algorithm came combine two frames into a single larger frame. In the preferred embodiment, array 27 comprises about twenty to fifty rows of cells in the shorter dimension and about 250 columns of cells in the longer dimension.

[0019] Scanning array 19 includes a horizontal scanning stage 31 and a vertical scanning stage 33. Scanning stages 31 and 33 enable one cell 29 at the time according to a predetermined scanning pattern. The scanning rate depends upon the maximum finger speed and the amount of blurring that can be tolerated. In the preferred embodiment, each cell 29 is scanned at a rate once each one to ten millisecond to produce a frame rate of 100 to 1,000 frames per second.

[0020] Input device 19 includes a power supply and scan control unit 35. Power supply and scan control unit 35 supplies a reference voltage to each cell 29 of array 27. Power supply and scan control 35 also operate scanning stages 31 and 33 to produce the desired scanning of cells 29.

[0021] An A/D converter 37 is connected to receive the output of each cell 29 of array 27. The output of A/D converter 37 is connected to-output logic 39. Output logic 39 processes the output of A/D converter 37 to capture successive images of a portion of the fingerprint of the user. Output logic 39 compares successive images to detect movement of the fingerprint. If output logic 39 detects movement, output logic computes the displacement of the fingerprint ridges over the scanning period, which in the preferred embodiment is one to ten milliseconds, and assembles the captured images into a complete fingerprint image.

[0022] Referring now to Figure 3, there is illustrated the structure and operation of a cell 29 according to the present invention. The cell of the preferred embodiment of the present invention is of type disclosed in Tartagni, U.S. Patent Application Serial No. 08/799,548, filed February 13, 1997, entitled Capacitive Distance Sensor, the disclosure of which is incorporated herein by reference. Each cell 29 includes a first conductor plate 47 and a second conductor plate 49 supported on a semiconductor substrate, which is preferably a conventional silicon substrate that may have a conventional shallow epitaxial layer defining an upper surface region thereof. The top surface of the substrate includes an insulating layer 41. Insulating layer 41 is preferably an oxide layer, which may be a conventional thermally grown silicon dioxide layer. Conductor plates 47 and 49 are covered by a protective coating 51 of a hard material, which protects cell 29 from moisture, contamination, abrasion, and electrostatic discharge.

[0023] Each cell 29 includes a high gain inverting amplifier 53. The input of inverter 53 is connected to a reference voltage source V_{REF} through an input capacitor 54. The output of inverter 53 is connected to an output V_{OUT}. The input of inverter 53 is also connected to conductor plate 47 and the output of inverter 53 is also connected to conductor plate 49, thereby creating a charge integrator whose feedback capacitance is the effective capacitance between conductor plates 47 and 49.

[0024] When a finger 23 is placed on the surface of protective layer 51, the surface of the skin over each sensor acts as a third capacitor plate separated from adjacent conductor plates 47 and 49 by a dielectric layer that includes protective coating 51 and a variable thickness of air. Because fingerprint valleys or pores will be farther from conductor plates 47 and 49 than finger ridges 57, sensors 29 beneath valleys or pores will have more distance between their conductor plates 47 and 49 and the skin surface than sensors under ridges. The thickness of this dielectric layer will modulate the capacitance coupling between plates 47 and 49 of each cell 29. Accordingly, sensors 29 under valleys or pores will exhibit a different effective capacitance than sensors 29 under ridges. As shown in Figure 3, the effective capacitance of sensor 29a is different from the effective capacitance of sensor 29b.

[0025] Sensors 29 work in two phases. During the first phase, the charge integrator is reset with a switch 59 by shorting the input and output of inserter 53. This causes inverter 53 to settle at its logical threshold. During the second phase a fixed charge is input to charge integrator, causing an output voltage swing inversely proportional to the feedback capacitance, which is the effective capacitance between conductor plates 47 and 49. For a fixed amount of input charge, the output of inverter 53 will range between two extremes depending on the effective feedback capacitance value. The first extreme is a saturated voltage level if the effective feedback capacitance is very small. The second extreme is a voltage close to the logical threshold, which is the reset value, when the effective feedback capacitance is large. Since the distance between the skin and the sensor changes the effective feedback capacitance of the charge integrator, the output of sensor 29a under ridge 57 will be different from the output of sensor 29b under valley 55.

[0026] The operation of the present invention to capture a fingerprint image is illustrated with respect to Figures 4 and 5. Figure 4 illustrates a sequence of partial fingerprint images 61-83 captured according to the present invention. Figure 5 illustrates a fingerprint image 85 assembled according to the present invention from partial images 61-83. In Figure 4, partial image 61 is captured first and partial image 62 is captured an instant later. It will be noted that partial images 61 and 62 share a number of common fingerprint features. Similarly, partial images 63 through 83 are captured at sequentially later instants of time and they each share fingerprint features with their sequentially adjacent partial images. Output logic 39 of Figure 2 compares successive partial images 61-83 to detect movement of the fingerprint. If output logic 39 detects movement, output logic computes the displacement of the fingerprint ridges over the scanning period, which in the preferred embodiment is one to ten milliseconds, and assembles the captured im-

ages into a complete fingerprint image 85.

[0027] From the foregoing, it may be seen that the present invention is well adapted to overcome the shortcomings of the prior art. The capacitive sensors of the present invention enable the device to be scanned at a high frame rate. The high frame rate enables a finger to be moved quickly over the device. Additionally, the high frame rate reduces the number of rows needed to capture the successive images. The device of the present invention is thus small in size, and it may be fabricated on a single integrated circuit chip. The present invention provides the advantages of electrical fingerprint detection at a cost lower than optical systems.

[0028] Although the present invention has been illustrated and described with respect to a presently preferred embodiment, it is to be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

Claims

1. A scanning fingerprint detection system, which comprises:

   an array of capacitive sensing elements, said array having a first dimension about the width of a fingerprint and a second dimension less than the length of a fingerprint, and each of said capacitive sensing elements having a size less than the width of a fingerprint ridge;
   means for scanning said array to capture an image of a portion of fingerprint; and,
   means for assembling captured images into a fingerprint image as a fingerprint is moved over said array.

2. The scanning fingerprint detection system as claimed in claim 1, wherein each capacitive sensing element of said array includes:

   a first conductor positioned on a substrate and defining a first plate of said capacitive sensing element;
   a second conductor portioned on said substrate and defining a second plate of said capacitive sensing element, said first and second conductors being spaced apart from each other;
   a reference voltage source providing an input voltage; and,
   an amplifier having an input and output, said input being coupled to said reference voltage and said first conductor, and said output being coupled to said second conductor.

3. The scanning fingerprint detection system as claimed in claim 1, wherein each capacitive sensing element of said array includes:

   a first conductor supported by a semiconductor substrate and defining a first plate of said capacitive sensing element;
   a second conductor supported by said semiconductor substrate and defining a second plate of said capacitive sensing element, said first and second conductors being spaced apart from each other;
   a reference voltage source providing an input voltage;
   an inverting amplifier having an input and output, said input being coupled to said reference voltage and said first conductor plate, and said output being coupled to said second conductor plate;
   an input capacitor connected between said reference voltage source and said input of said inverting amplifier; and,
   a switch connected between said input and said output of said inverting amplifier.

4. The scanning fingerprint detection system as claimed in claim 1, wherein said first dimension is about one-half inch and said second dimension is about one-tenth inch.

5. A scanning fingerprint detector, which comprises:
   an array of capacitive sensing elements, said array having a first dimension about the width of a fingerprint and a second dimension less than the length of a fingerprint, and each of said capacitive sensing elements having a size less than the width of a fingerprint ridge.

6. The scanning fingerprint detection system as claimed in claim 5, wherein each capacitive sensing element of said array includes:

   a first conductor positioned on a substrate and defining a first plate of said capacitive sensing element;
   a second conductor portioned on said substrate and defining a second plate of said capacitive sensing element, said first and second conductors being spaced apart from each other;
   a reference voltage source providing an input voltage; and,
   an amplifier having an input and output, said input being coupled to said reference voltage and said first conductor, and said output being coupled to said second conductor.

7. The scanning fingerprint detection system as claimed in claim 2 or claim 6, wherein said amplifier includes an inverting amplifier.

8. The scanning fingerprint detection system as claimed in claim 2 or claim 6, including a protective coating deposited over said first and second conductor.

9. The scanning fingerprint detection system as claimed in claim 2 or claim 6, including an input capacitor coupled between said reference voltage source and said input of said amplifier.

10. The scanning fingerprint detection system as claimed in claim 2 or claim 6, including a switch connected between said input and said output of said amplifier.

11. The scanning fingerprint detection system as claimed in claim 5, wherein each capacitive sensing element of said array includes:

a first conductor supported by a semiconductor substrate and defining a first plate of said capacitive sensing element;
a second conductor supported by said semiconductor substrate and defining a second plate of said capacitive sensing element, said first and second conductors being spaced apart from each other;
a reference voltage source providing an input voltage;
an inverting amplifier having an input and output, said input being coupled to said reference voltage and said first conductor plate, and said output being coupled to said second conductor plate;
an input capacitor connected between said reference voltage source and said input of said inverting amplifier; and,
a switch connected between said input and said output of said inverting amplifier.

12. The scanning fingerprint detection system as claimed in claim 5, wherein said first dimension is about one-half inch and said second dimension is about one-tenth inch.

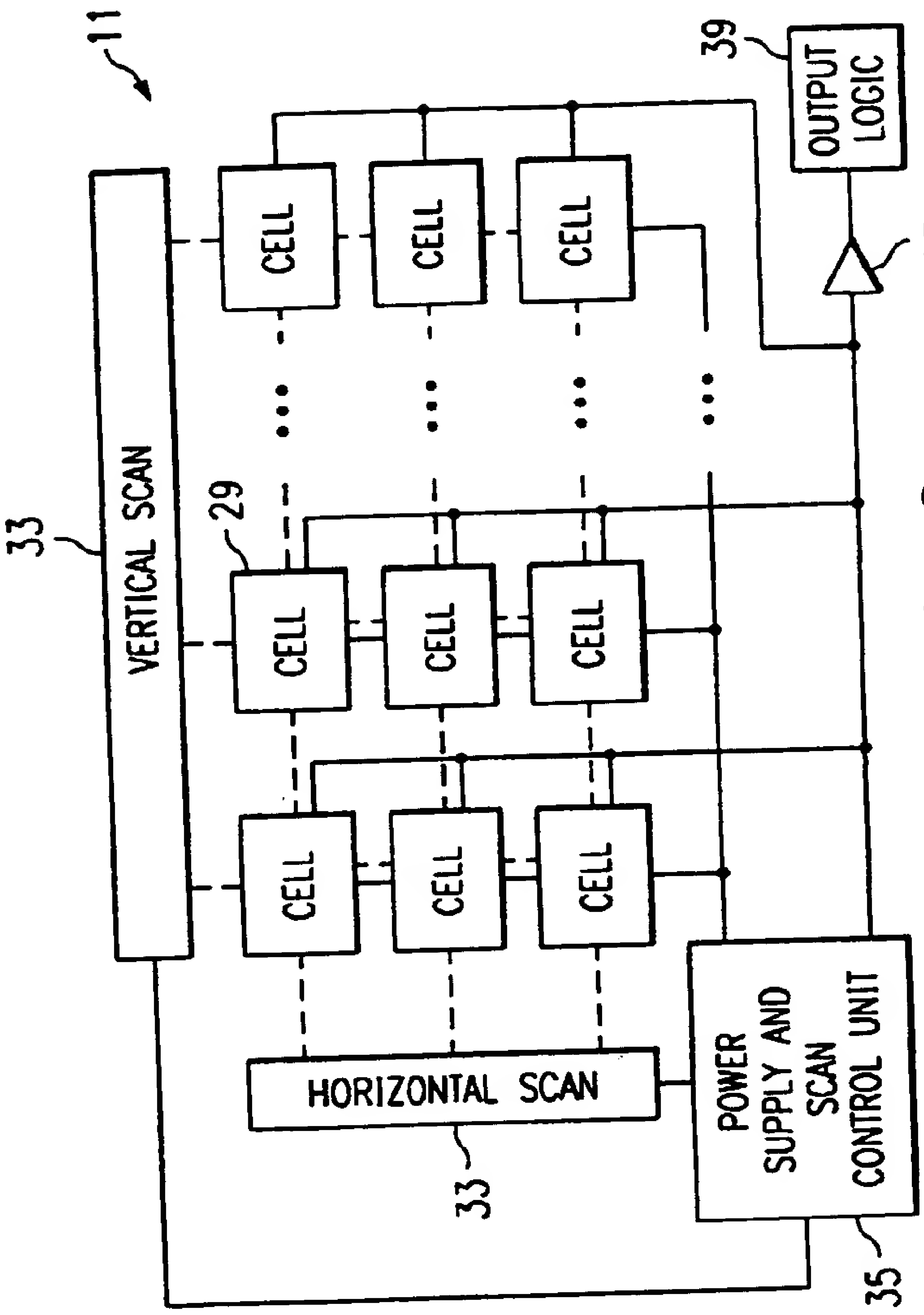

FIG. 2

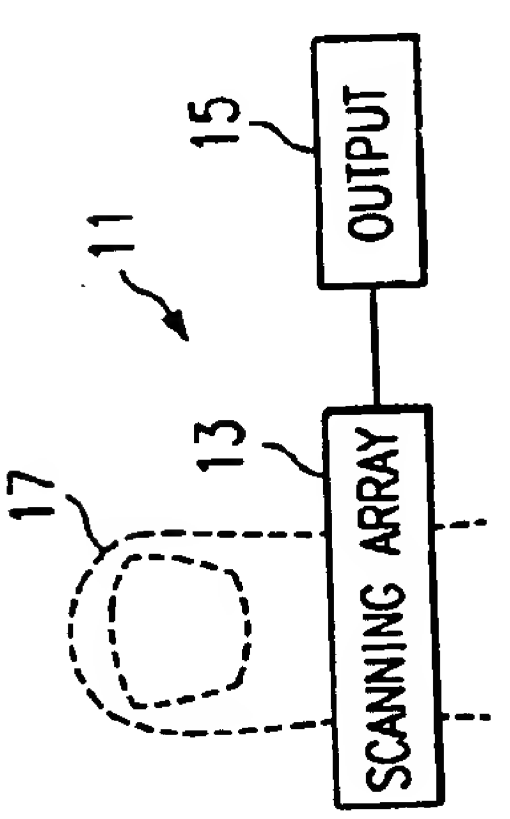

FIG. 1

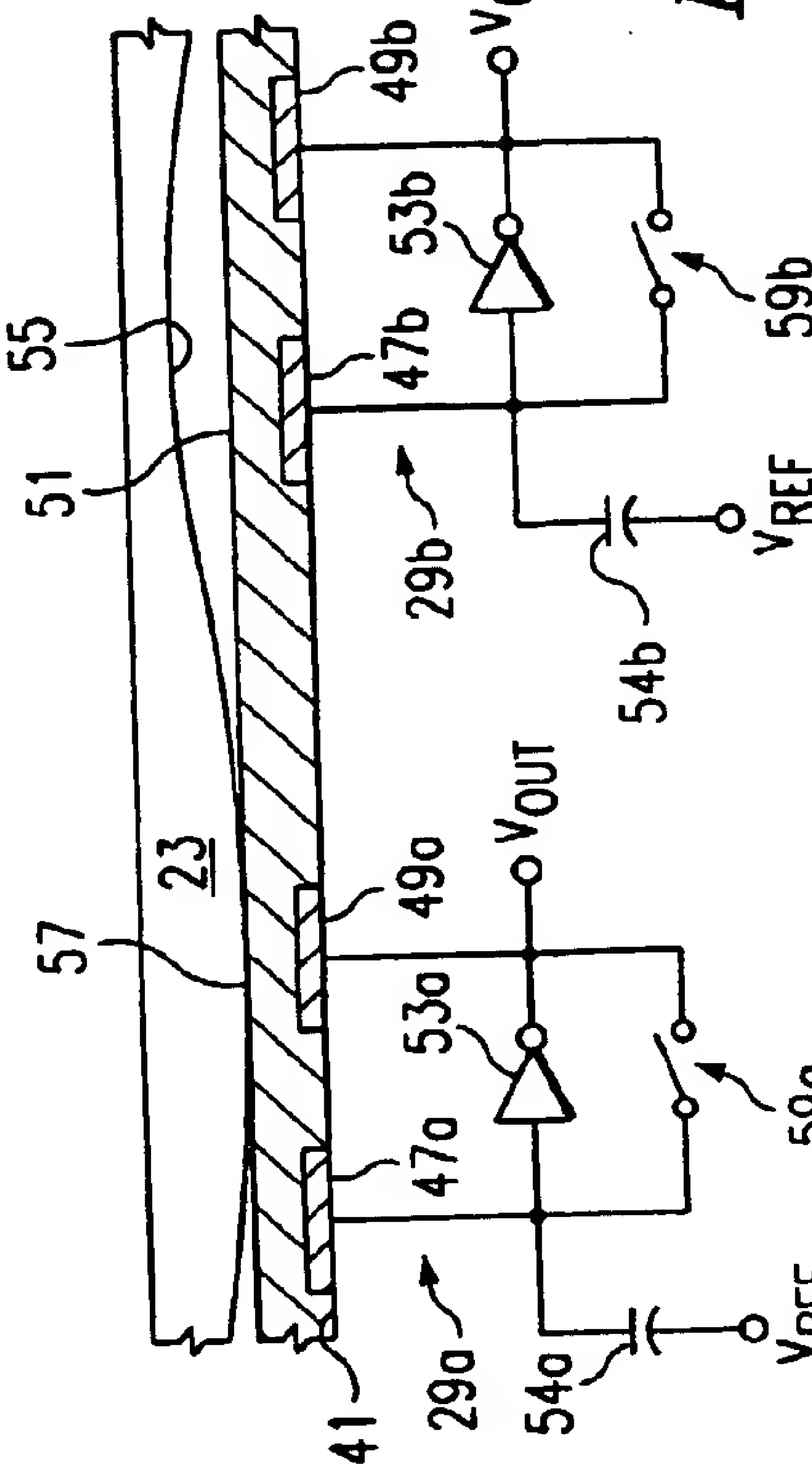

FIG. 3

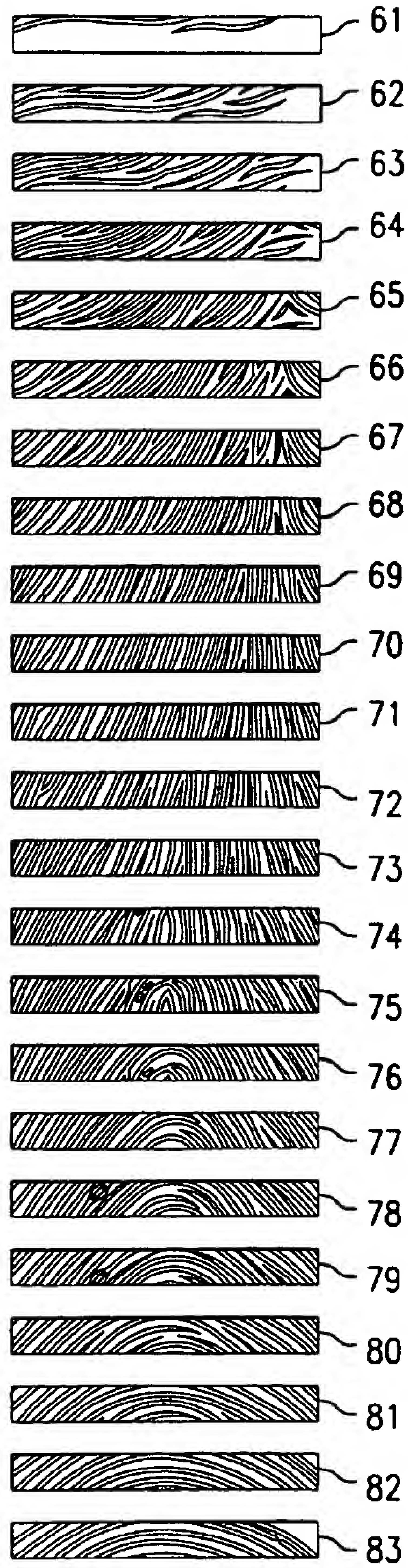

FIG. 4

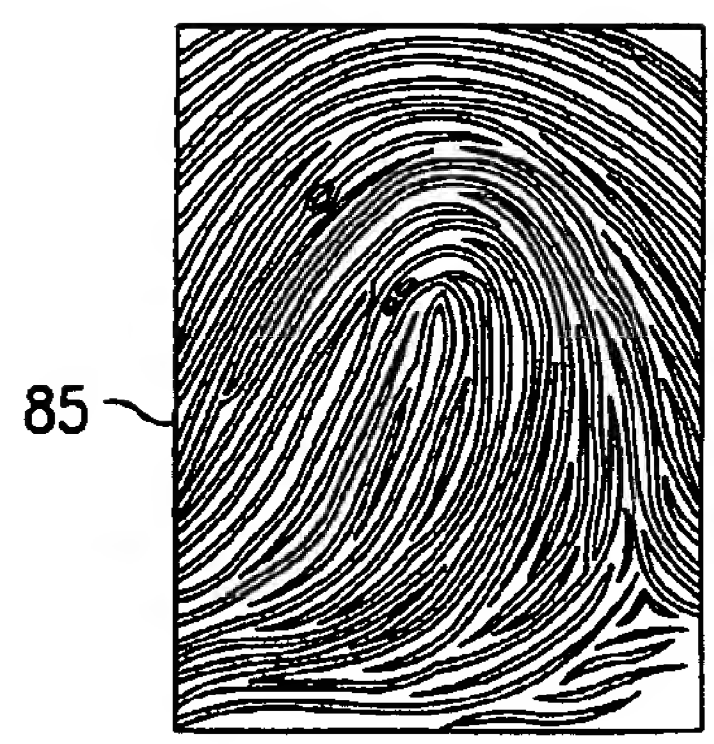

FIG. 5

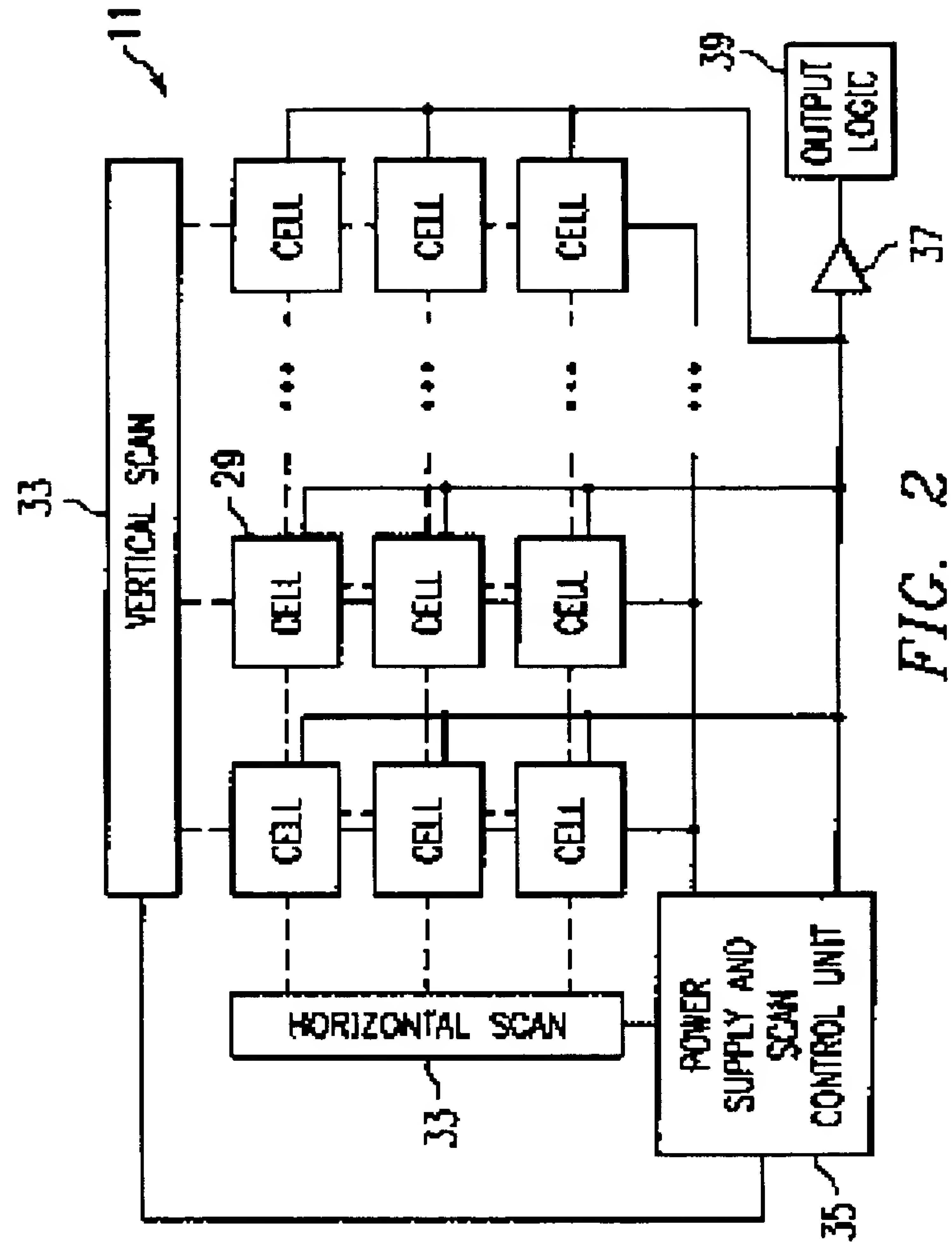

FIG. 2

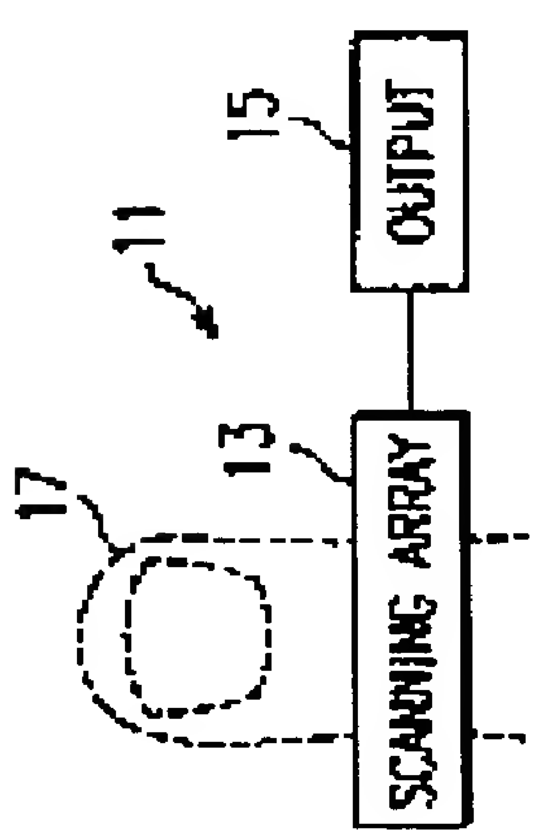

FIG. 1

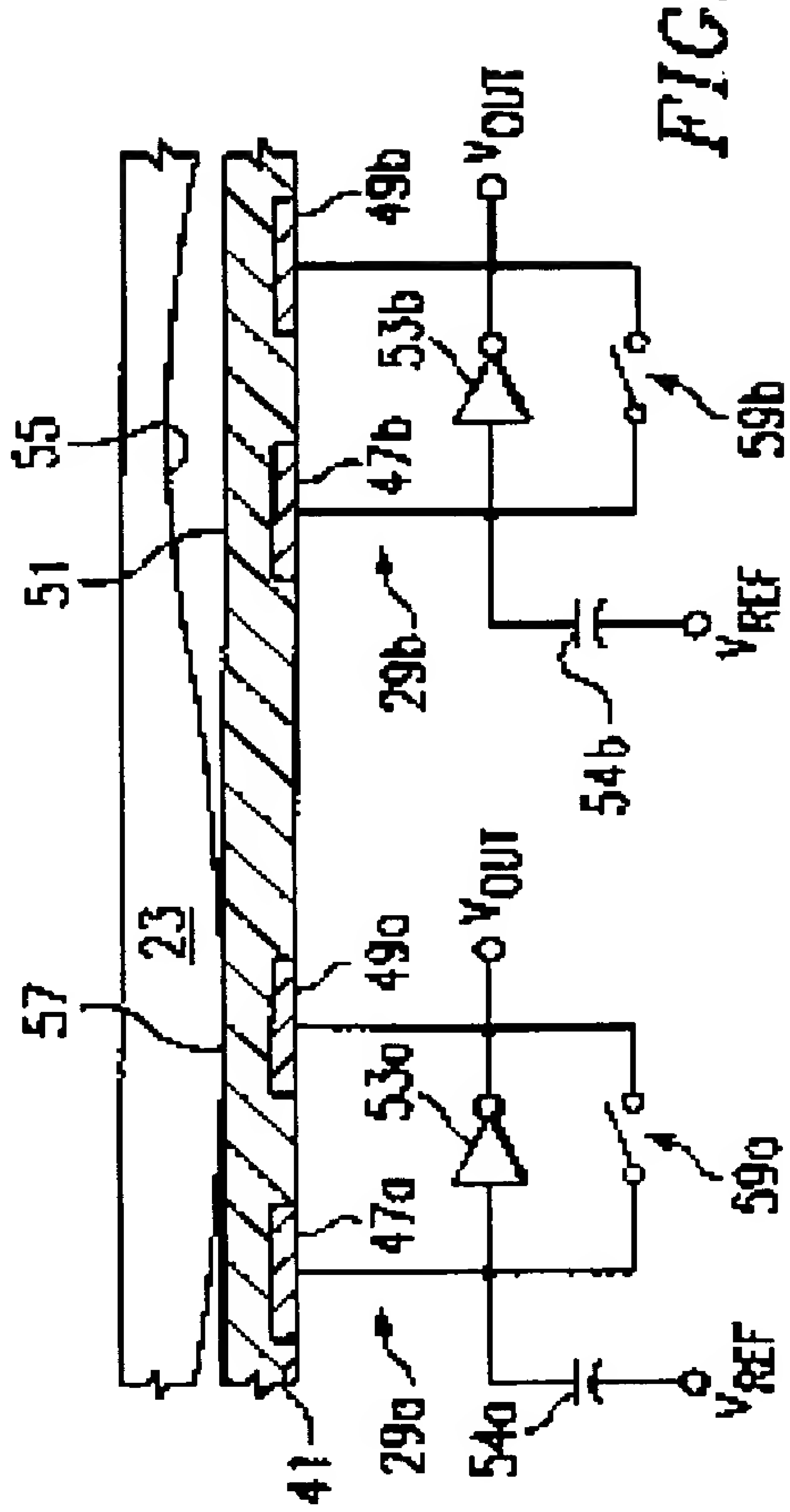

FIG. 3

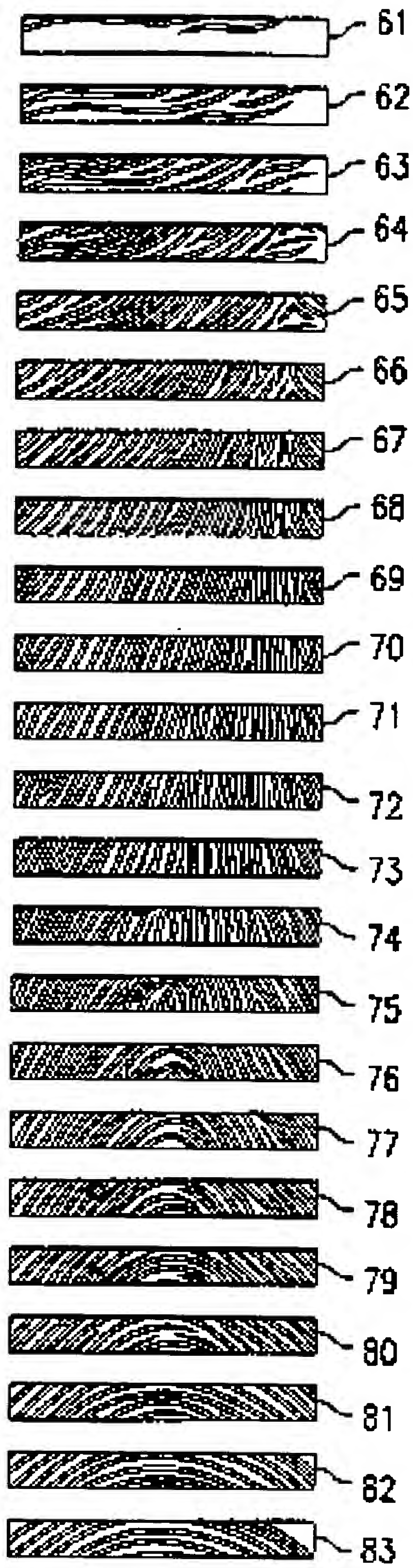

FIG. 4

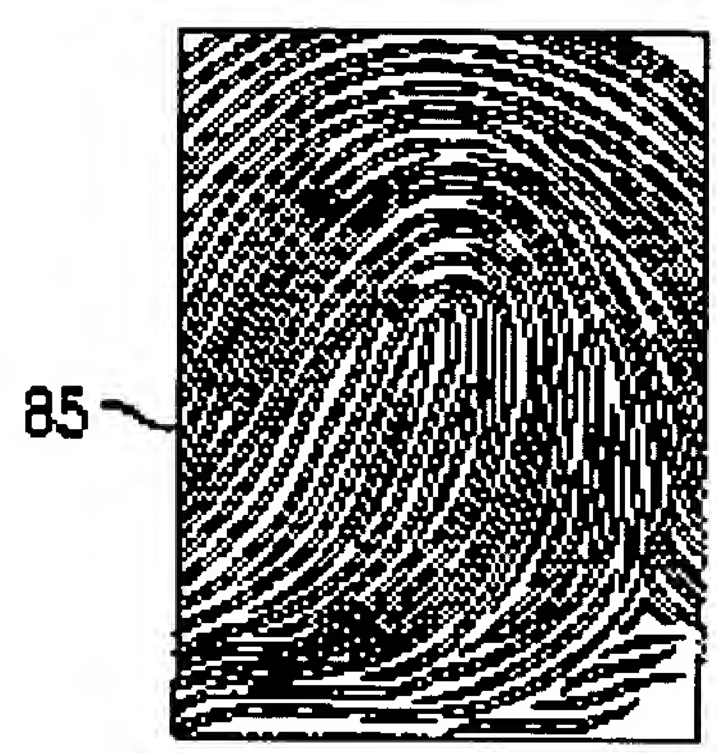

FIG. 5

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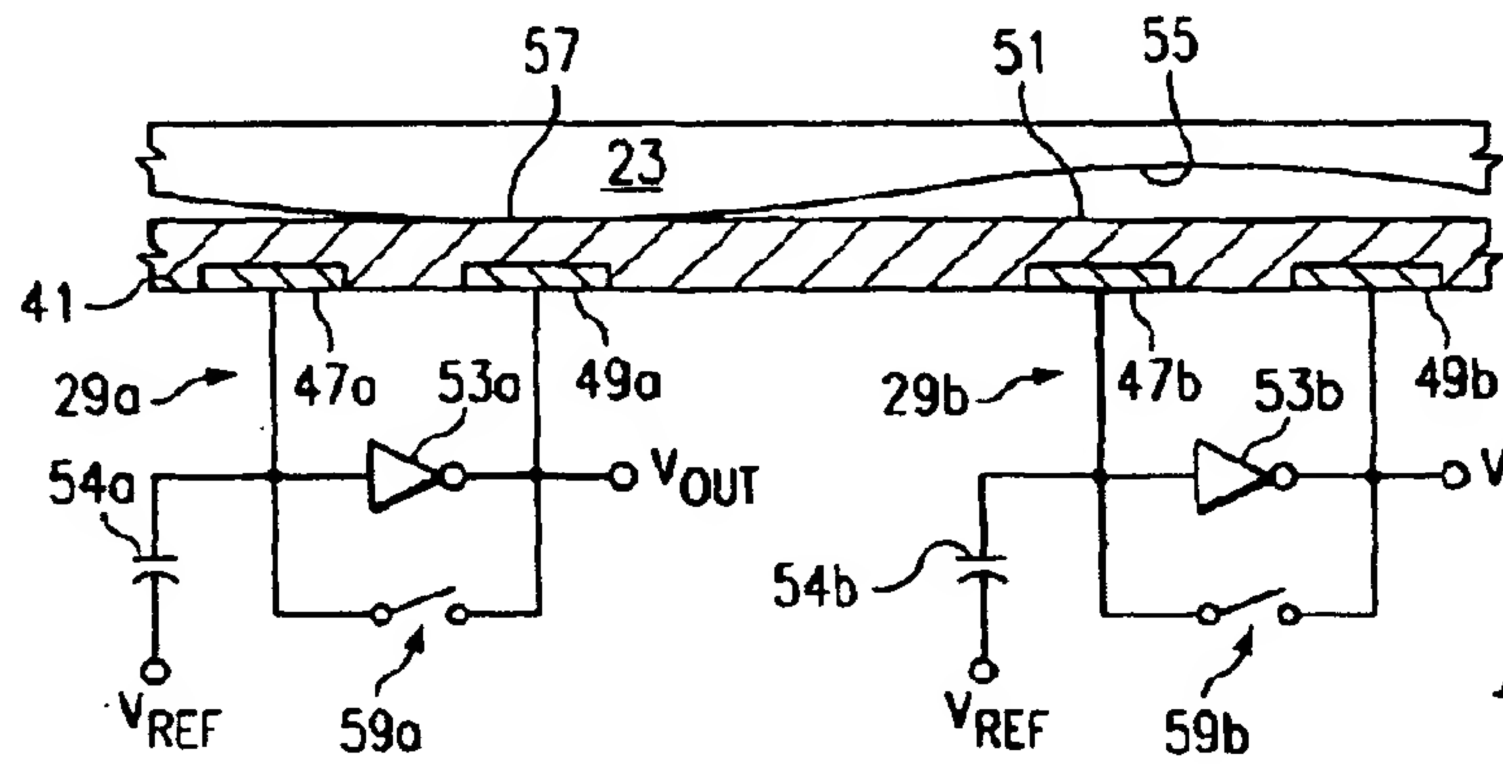

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	EP 0 790 479 A (SGS THOMSON MICROELECTRONICS) 20 August 1997 (1997-08-20) * the whole document * ---	1-12	G06K9/00
Y	EP 0 813 164 A (THOMSON CSF) 17 December 1997 (1997-12-17) * abstract; figures 1-12 * ---	1-12	
A	US 4 933 976 A (FISHBINE BRIAN H ET AL) 12 June 1990 (1990-06-12) * abstract * ---	1-12	
A	TARTAGNI M ET AL: "FP 12.3: A 390DPI LIVE FINGERPRINT IMAGER BASED ON FEEDBACK CAPACITIVE SENSING SCHEME" IEEE INTERNATIONAL SOLID STATE CIRCUITS CONFERENCE,US,IEEE INC. NEW YORK, vol. 40, 1 February 1997 (1997-02-01), pages 200-201,456, XP000753070 ISSN: 0193-6530 * the whole document * ---	1-12	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
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A	TARTAGNI M ET AL: "A FINGERPRINT SENSOR BASED ON THE FEEDBACK CAPACITIVE SENSING SCHEME" IEEE JOURNAL OF SOLID-STATE CIRCUITS,US,IEEE INC. NEW YORK, vol. 33, no. 1, 1998, pages 133-142, XP000766627 ISSN: 0018-9200 * the whole document * -----	1-12	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 November 2000	Granger, B

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